Finger Ridge-Count Asymmetry and Diversity in Andean Indians and Interpopulation Comparisons

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ABSTRACT A separate analysis of ulnar and radial finger ridge-counts, obtained from 115 Aymara Indians (55 males and 60 females) of northern Chile, was performed. From these variables, directional asymmetry, fluctuating asymmetry, indices of bilateral asymmetry ($\sqrt{A^2}$), and intraindividual diversity ($s/\sqrt{5}$) were calculated for each sex.

The results show that most bimanual differences for the ridge-counts are not statistically significant in the Aymara, except for radial counts in female first and second fingers (right hand means are larger), while most ulnar-radial differences are highly significant in both sexes (radial values exceed ulnar ones). Most sex differences do not reach statistical significance, although males have more ridge-counts, lower directional asymmetry, somewhat lower fluctuating asymmetry, and lower indices of asymmetry and diversity than females. As fluctuating asymmetry is not larger in males, the dermatoglyphic findings do not indicate support for the hypothesis that males are less canalized than females.

In accordance with the findings of other authors, interpopulation comparisons in the indices of asymmetry and diversity show ethnic differences. Both indices tend to be low in samples of African ancestry, high in samples of European origin, and intermediate in the Aymara, while Indian groups are characterized by high asymmetry and low diversity values. Moreover, the data reveal a geographical trend in that asymmetry and diversity values tend to decrease from the northern to the southern hemisphere in populations of Europe, the Middle East, and Africa, thus indicating greater ridge-count variability and heterogeneity among fingers in northern populations. It is assumed that this gradient primarily reflects different degrees of miscegenation and heterozygosity. Am J Phys Anthropol 105:377–393, 1998. © 1998 Wiley-Liss, Inc.

For some decades, the investigation of bilateral asymmetry has been a focus of biological research. Bilaterally symmetric structures of the body are influenced by genetic and environmental factors during growth and development. Studies have demonstrated that certain environmental stress factors can increase bilateral asymmetry in a trait (e.g., Harris and Nweeia, 1980; Mooney et al., 1985; Parsons, 1992; Sciulli et al., 1979). The magnitude of bilateral asymmetry is thought to reflect the degree of local developmental disturbances. In the literature, two main categories of asymmetry are

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differentiated, namely the directional (signed) and the fluctuating (nonsigned, random, absolute) asymmetry. Directional asymmetry indicates that a bilateral trait is more developed on one side than on the other, whereas fluctuating asymmetry is defined as the random quantitative difference between the two sides of a bilateral trait (Van Valen, 1962). Directional asymmetry in a character is believed to be developmentally controlled, while fluctuating asymmetry is considered a result of developmental noise (Waddington, 1957), caused by stress factors (Doyle and Johnston, 1977). Thus, fluctuating asymmetry may be an indirect measure of developmental stability. Livshits and Kobyliansky (1991) reviewed relationships between the magnitude of fluctuating asymmetry, morbidity, and heterozygosity.

Bilateral asymmetry has mainly been studied in dental (e.g., Groeneveld and Kieser, 1991; Harris and Nweeia, 1980; Hershkovitz et al., 1987, 1993; Kieser et al., 1986; Townsend and Brown, 1980), anthropometric (Garn et al., 1976; Livshits and Kobyliansky, 1989; Livshits and Smouse, 1993; Malina and Buschang, 1984; Plato et al., 1980; Schell et al., 1985), and dermatoglyphic traits (Jantz, 1975; Karev, 1990; Kobyliansky and Micle, 1987, 1989; Micle and Kobyliansky, 1987; Roche et al., 1979; Vona and Porcell, 1983). The specific feature of dermatoglyphic characters is that they could not be altered by postnatal environmental influences, in contrast to anthropometric traits. Therefore, they may offer new insights regarding the formation of bilateral structures during prenatal development. Micle and Kobyliansky (1991) recently reviewed the implications of directional and fluctuating asymmetry for quantitative dermatoglyphic traits. They stated that an increase of the asymmetry level is one of the possible effects of environmental stress on dermatoglyphic structures. Jantz and Webb (1980) demonstrated the importance of dermatoglyphic fluctuating asymmetry as a measure of canalization. Furthermore, increased levels of dermatoglyphic asymmetry have been observed in patients with familial patterns of cleft-lip and cleft-palate (Adams and Niswander, 1967; Floris, 1992; Woolf and Gianas, 1976, 1977), in patients with fetal alcohol syndrome (Wilber et al., 1993), in dyslexics (Sorenson-Jamison, 1988), in schizophrenics (Markow and Wandler, 1986), in chromosomal mosaics (Polani and Polani, 1969), and in individuals with minor physical anomalies (Green et al., 1994) as compared to controls.

In many studies on dermatoglyphic asymmetry, only one ridge-count is considered for each finger, namely the higher ridge-count of each whorl, and the only value of each loop irrespective of its direction. In order to evaluate dermatoglyphic asymmetry, the separate analyses of both the radial and ulnar counts finger-by-finger provide much more information, as has been shown by different authors (e.g., Jantz and Hawkinson, 1980; Jantz and Owsley, 1977; Jantz et al., 1982; Karev, 1988; Roberts and Coope, 1975). Principal components analysis has further demonstrated differences between radial and ulnar sides of fingers (Roberts, 1979; Santos and Meier, 1990; Siervogel et al., 1978).

Besides directional and fluctuating asymmetries, two further variables are distinguished in the literature: the indices of asymmetry and intraindividual diversity. The index of asymmetry describes the ridge-count variation among homologous fingers while the index of diversity quantifies differences between non-homologous fingers. The importance of these indices is emphasized by the results of principal components analysis applied on a set of 66 dermatoglyphic variables (Micle and Kobyliansky, 1986). The five components that were extracted included a diversity and an asymmetry component. Moreover, comparative studies by Jantz (1974, 1975) on groups of European and African ancestry demonstrated that finger ridge-count asymmetry and diversity display ethnic and populational variation.

An examination of the literature shows that there are several studies on dermatoglyphic asymmetry and intraindividual diversity of finger ridge-counts in populations of mainly Indo-European ancestry (Chakraborty et al., 1982; Jantz, 1975; Karev, 1990; Kobyliansky and Micle, 1987, 1988, 1989; Kobyliansky et al., 1986; Leguebe and

Vrydagh-Laoureux, 1978; Micle and Kobyliansky, 1987; Roche et al., 1979; Vona and Porcell, 1983) and African ancestry (Jantz, 1975; Salzano and Benevides, 1974), while, to the author's knowledge, published data on Amerindians are missing until now. In order to fill this gap, the present study reports observations on asymmetry and diversity in an Amerindian group, the Aymara Indians. These Indians inhabit the South American Andes region of western Bolivia, southern Peru, and northern Chile. The Aymara are characterized by low degrees of white (8.2%) and black (2.2%) admixtures (Salzano and Callegari-Jacques, 1988). Their subsistence activities are primarily agricultural and pastoral and they may generally be considered to be of a low socioeconomic level. The Aymara are of special interest as they represent a population that lives at high altitude under hypobaric hypoxic stress.

The purpose of this paper is twofold: 1) to provide intraindividual and intrapopulational data on directional asymmetry, fluctuating asymmetry, the index of asymmetry, and the index of diversity of finger ridge-counts in Amerindians; and 2) to compare, at an interpopulational level, ridge-count asymmetry and diversity values of samples from different ethnic backgrounds in order to get an insight into population differences.

POPULATION AND METHODS

The population

The observations of the present paper were obtained during an investigation on Aymara-speaking Indians between November and December 1987 in the community of Putre (3,530 m), Parinacota Province, Department "Region 1," northern Chile. They are part of a general anthropological investigation of the Aymara in the community of Putre. Details about the study design, as well as ethnogenetic, anthropometric, dermatoglyphic, and serologic results can be found in Dittmar (1994a,b,c, 1995, 1996). The survey was performed in a school in Putre where approximately 95% of the Aymara children could be investigated. Data on 115 individuals (55 males and 60 females) between the ages of 6 and 25 years are included in this report. The Aymara studied spend their whole lives at altitudes above 3,000 m and were in apparently good health. Ethnicity determination was performed by applying the surname method, analyzing maternal and paternal surnames as described in Schull and Rothhammer (1977). An individual was considered to be Aymara if his patronyms and matronyms were of Aymara origin.

Anthropological and statistical methods

Fingerprints were collected from both hands of both sexes using common ink and tape. All ridges were counted according to conventional methods as described in Holt (1968). Ridge-counts comprise the ulnar and radial counts of each of the ten fingers, forming a set of 20 variables.

For each individual the following measures of asymmetry and diversity were determined: Directional and fluctuating asymmetries were evaluated from the ulnar and radial ridge-counts of each of the ten fingers. *Directional asymmetry* was calculated by taking the signed difference between the right and left digits, designated as (R-L), following Jantz and Webb (1980). Various measures exist for evaluating *fluctuating asymmetry* in finger ridge-counts (Jantz and Webb, 1980; Micle and Kobyliansky, 1988; Wolf and Gianas, 1976). In this study, it was calculated by taking the absolute (unsigned) difference between the right and left digits, designated as (|R-L|), according to Jantz and Webb (1980).

In addition, the *index of asymmetry* of ridge-counts was examined using the measure of Jantz (1975):

$$\sqrt{A^2} = \sqrt{\sum_{i=1}^{5} (R_i - L_i)^2}$$

where $(R_i - L_i)$ is the difference between the ridge-counts on the corresponding right and left hand *i*th fingers. Differences between homologous digits were squared in order to emphasize the larger and presumably more important asymmetries.

The intraindividual measure of *diversity* is used to analyze the differences between non-homologous fingers. It was evaluated using the measure of Holt (1960), modified

by Jantz (1975):

$$s/\sqrt{5} = \sqrt{\frac{\sum_{i=1}^{5} q_i^2 - Q^2/5}{5}}$$

where q_i is the sum of corresponding counts of the *i*th pair of homologous fingers and Q is an individual's total ridge-count (TRC). With regard to the calculation of q_i, the higher value of the two possible ridge-counts was considered. Correspondingly, the TRC is the sum of the higher of ulnar and radial ridge-counts over all ten digits. The formula removes effects of asymmetry and quantifies only the diversity between non-homologous fingers.

Ulnar and radial ridge-counts of each finger, total ridge-count (TRC), bilateral summed ulnar ridge-count (URC), and bilateral summed radial ridge-count (RRC) were calculated and presented by their means, standard errors of means, and standard deviations for each sex separately.

The Kolmogorov-Smirnov test was applied to test whether the data fit a normal distribution. Sex differences were tested for statistical significance by means of *t* tests for equal or unequal variances in case of normally distributed variables and through the nonparametric Mann-Whitney *U* tests in case of not normally distributed variables. For the analysis of bimanual differences (right vs. left) and side differences (ulnar vs. radial), paired *t* tests (normally distributed variables) or Wilcoxon's matched-pairs signed-ranks test (not normally distributed variables) were employed. Through the Wilcoxon matched-pairs signed-ranks test in which direction (positiveness or negativeness) as well as the relative magnitude of the differences between the values is considered, directional asymmetry values were tested for statistical significance. The Friedman test was used in order to analyze the five non-homologous finger pairs for differences in their amounts of directional and fluctuating asymmetries. Pairwise Spearman rank coefficients of correlation were estimated between the values of directional asymmetry, between the values of fluctuating asymmetry, and between $\sqrt{A^2}$, $s/\sqrt{5}$, and TRC. All calculations were performed separately for males and females.

The finger ridge-count diversity and asymmetry values of the Aymara were compared to those of populations from different regions of the world. A discriminant analysis was carried out in order to show clustering of populations of the same ethnic background and particularly the group-specific classification of the Aymara.

In all cases, the level of significance (*P*) was taken as equal to, or less than, 0.05. The statistical analyses were run at the University of Mainz computer center using SPSS/PC software for MS Windows, version 6.0 (Hermann et al., 1994).

RESULTS

Ulnar and radial finger ridge-counts

First, the descriptive statistics for the 20 ulnar and radial finger ridge-counts are presented finger-by-finger for Aymara males and females (Table 1). In both sexes, the highest ulnar as well as radial ridge-count means are to be found on digits 1 and 4, the values of digit 1 being the highest for ulnar counts and of digit 4 for radial counts. The lowest ulnar counts occur on digits 3 and 5, and the lowest radial counts on digits 2 and 5.

Bilateral differences in ridge-count means on homologous fingers of the right and left hands were tested for statistical significance through Wilcoxon's matched-pairs signed-ranks test because the distributions of ridge-count variables do not approximate the normal distribution. In males, none of the five ulnar and five radial bilateral differences attains statistical significance at the 5% level. In females, out of the ten bimanual comparisons only two differences, those of the first and second fingers for radial ridge-counts, are statistically significant ($P < 0.001$, higher ridge-counts on the right hand).

Next, comparisons of ridge-count means on radial and ulnar sides of each of the ten fingers were performed. It is noticeable that in both sexes radial ridge-counts exceed ulnar ones on most digits. In each sex, out of the ten ulnar-radial differences seven are highly significant ($P < 0.001$, Wilcoxon's matched-pairs signed-ranks test; results are not indicated in Table 1), namely, for the

TABLE 1. Means, standard errors of means, and standard deviations for ulnar and radial finger ridge-counts in Chilean Aymara Indians

Finger R = right L = left	Males (n = 55) Mean ± SE	SD	Females (n = 60)[1,3] Mean ± SE	SD	Difference (male–female) and significance[2,3]	
Ulnar						
1 R	11.18 ± 1.17	8.68	9.65 ± 1.11	8.63	+1.53	n.s.
L	11.56 ± 1.20	8.93	10.50 ± 1.09	8.48	+1.06	n.s.
2 R	9.51 ± 1.32	9.79	6.70 ± 1.15	8.87	+2.81	n.s.
L	8.47 ± 1.21	9.01	8.10 ± 1.08	8.39	+0.37	n.s.
3 R	3.94 ± 1.06	7.89	2.58 ± 0.77	6.00	+1.36	n.s.
L	3.47 ± 0.94	6.95	3.12 ± 0.83	6.43	+0.35	n.s.
4 R	9.60 ± 1.18	8.77	8.27 ± 0.97	7.54	+1.33	n.s.
L	9.58 ± 1.11	8.21	7.60 ± 1.03	8.02	+1.98	n.s.
5 R	1.84 ± 0.60	4.47	0.43 ± 0.26	2.04	+1.41	*
L	1.64 ± 0.58	4.31	1.13 ± 0.43	3.36	+0.51	n.s.
Radial						
1 R	16.45 ± 0.95	7.06	13.02 ± 0.91	7.04	+3.43	**
L	15.25 ± 1.07	7.93	10.12 ± 0.91***	7.03	+5.13	***
2 R	9.38 ± 0.98	7.25	9.08 ± 0.81	6.26	+0.30	n.s.
L	8.42 ± 1.01	7.51	6.00 ± 0.76***	5.93	+2.42	n.s.
3 R	13.22 ± 0.73	5.39	12.40 ± 0.70	5.39	+0.82	n.s.
L	13.82 ± 0.78	5.81	11.75 ± 0.79	6.14	+2.07	n.s.
4 R	17.49 ± 0.76	5.63	16.13 ± 0.84	6.51	+1.36	n.s.
L	17.60 ± 0.82	6.06	15.97 ± 0.91	7.06	+1.63	n.s.
5 R	12.54 ± 0.67	4.94	10.18 ± 0.68	5.29	+2.36	*
L	12.89 ± 0.71	5.24	10.97 ± 0.77	5.93	+1.92	n.s.

[1] Asterisks behind SE values indicate significance levels of differences between homologous right and left fingers (Wilcoxon's matched-pairs signed-ranks test, two-tailed).
[2] Sex differences were tested using Mann-Whitney's *U* test (two-tailed).
[3] Significance levels: *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$.

right first finger, the right and left third, fourth, and fifth fingers. For the left first finger, differences are statistically significant at the 5% level in males and nonsignificant in females. Ulnar-radial differences on the second finger are not significant, except for the right one in females ($P < 0.05$).

Sex differences, expressed as M-F, are all positive, showing that males exhibit higher ulnar and radial means for each of the ten digits than females. Few of the observed sex differences are statistically significant. Out of the ten ulnar ridge-counts, only the difference on the right fifth finger is statistically significant ($P < 0.05$, Mann-Whitney's U test). With regard to the ten radial ridge-counts, sex differences are only significant for right ($P < 0.01$) and left counts ($P < 0.001$) on the first finger, and the right count on the fifth finger ($P < 0.05$).

Directional and fluctuating asymmetries

Based on radial and ulnar finger ridge-counts, directional and fluctuating asymmetries in the Aymara were calculated. The objective is to characterize the Aymara sample with regard to various aspects of asymmetry (differences between non-homologous fingers, ulnar-radial differences, and sex differences). All subsequent side and sex comparisons regarding directional and fluctuating asymmetries were checked for statistical significance by means of nonparametric tests because the variables did not meet the criterion of normal distribution.

Directional asymmetry. As can be seen in Figure 1, directional asymmetry exhibits a distinct pattern when viewed over the five finger pairs. On ulnar and on radial sides, especially in females, the first and second finger pairs tend to display the greatest level of asymmetry, the fourth and fifth finger pairs the lowest. To test the differences in directional asymmetry between non-homologous finger pairs for statistical significance, the Friedman two-way ANOVA was utilized among all five finger pairs, separately for the ulnar and radial directional asymmetries. The results show that for ulnar sides differences in asymmetry between fingers are nonsignificant at the 5% level in both sexes. The same is found for radial asymme-

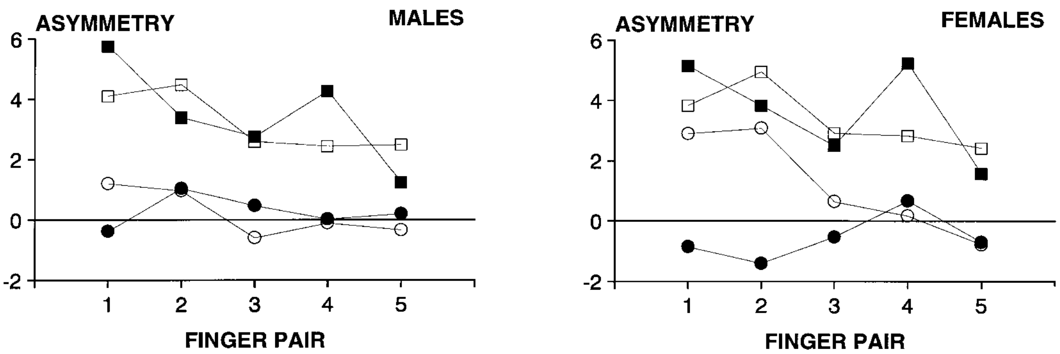

Fig. 1. Mean asymmetry values over the five finger pairs by sex: ●—●, ulnar directional; ○—○, radial directional; ■—■, ulnar fluctuating; □—□, radial fluctuating. Ulnar-radial differences reach statistical significance for directional asymmetry on first and second digits in females. For fluctuating asymmetry, ulnar-radial differences are significant for fourth and fifth fingers in both sexes, and second fingers in females.

tries in males, while in females radial differences are statistically highly significant ($\chi^2 = 27.11$, d.f. 4, $P = 0.0000$).

As has been shown above for finger ridge-counts, the Aymara exhibit significant bilateral differences only in radial counts on the first and second fingers in women (cf. Table 1). Therefore, only the directional asymmetry measures for the first and second fingers may be of importance, while the rest possibly represents noise figures that do not have much significance.

Sex differences in directional asymmetry are small. They only reach statistical significance for radial values on the first finger; here, females show a higher mean asymmetry value than males ($P < 0.05$, Mann-Whitney *U* test).

Table 3 gives the results of the Spearman rank correlation analysis between the ten variables of directional asymmetry. Most of the 45 coefficients are low and not statistically significant from zero at the 5% level, ranging from -0.46 to $+0.47$ in males, and from -0.45 to $+0.34$ in females. In both sexes, most correlations among ulnar variables and among radial variables are positive, while correlations between ulnar and radial values are predominantly negative. Statistical significance is to be found only for seven coefficients in males and four in females. The highest correlations ($P < 0.001$) occur in males between ulnar counts of digits 1 and 4, and between ulnar and radial counts of the first digit; in females, between ulnar and radial counts of the second digit.

Fluctuating asymmetry. Table 2 presents means, standard errors of means, and standard deviations for the ten fluctuating ($|R\text{-}L|$) asymmetry variables that were separately calculated from ulnar and radial finger ridge-counts of Aymara males and females.

For ulnar and radial fluctuating asymmetry values, males and females exhibit equal distribution patterns over the five finger pairs (Table 2 and Fig. 1). In each sex, the first and fourth fingers display the highest rate of ulnar asymmetry, while radial asymmetry is most pronounced on the first and second fingers. Differences among the five non-homologous finger pairs regarding their amounts of fluctuating asymmetry were analyzed by means of the Friedman two-way ANOVA, carried out separately for ulnar and radial values. The results show that for ulnar asymmetries differences between finger pairs are statistically highly significant in both sexes ($P = 0.0000$). In contrast, differences in radial fluctuating asymmetries are smaller, being nonsignificant in males ($P = 0.08$) and significant in females ($P = 0.01$).

In both sexes, radial-ulnar differences are statistically significant on the fourth ($P < 0.05$ in males, $P < 0.01$ in females) and fifth fingers ($P < 0.01$) and, in addition, in females on the second finger ($P < 0.05$, Wilcox-

TABLE 2. Means, standard errors of means, and standard deviations for fluctuating (|R-L|) asymmetries of finger ridge-counts in Aymara males and females

Finger Pair	Fluctuating asymmetry				Significance of sex difference[2,3]
	Males[1,3]		Females[1,3]		
	Mean ± SE	SD	Mean ± SE	SD	
Ulnar					
1	5.76 ± 0.80	5.96	5.15 ± 0.76	5.89	n.s.
2	3.40 ± 0.72	5.36	3.83 ± 0.64	5.00	n.s.
3	2.76 ± 0.65	4.80	2.50 ± 0.60	4.68	n.s.
4	4.27 ± 0.66	4.92	5.23 ± 0.72	5.55	n.s.
5	1.25 ± 0.37	2.76	1.57 ± 0.49	3.81	n.s.
Radial					
1	4.11 ± 0.49	3.64	3.83 ± 0.45	3.52	n.s.
2	4.49 ± 0.71	5.28	4.95 ± 0.66	5.10*	n.s.
3	2.60 ± 0.24	1.75	2.92 ± 0.38	2.95	n.s.
4	2.44 ± 0.35	2.58*	2.83 ± 0.37	2.84**	n.s.
5	2.49 ± 0.24	1.80**	2.42 ± 0.35	2.71**	n.s.

[1] Asterisks behind SD values indicate significance levels of ulnar-radial differences for each finger pair (Wilcoxon matched-pairs signed-ranks test, two-tailed).
[2] Sex differences were tested using Mann-Whitney's *U* test (two-tailed).
[3] Significance levels: $*P \leq 0.05$, $**P \leq 0.01$.

TABLE 3. Spearman coefficients of correlation between directional asymmetry values (A) and fluctuating asymmetry values (B) for male (above diagonal) and female Aymara (below diagonal)

A. Directional asymmetry

Finger pair	1 ulnar	2 ulnar	3 ulnar	4 ulnar	5 ulnar	1 radial	2 radial	3 radial	4 radial	5 radial
1 ulnar	—	+0.24	−0.01	+0.47***	+0.07	−0.46***	−0.26	+0.13	+0.01	−0.22
2 ulnar	+0.34**	—	+0.10	+0.23	−0.05	−0.13	−0.31*	−0.12	−0.16	+0.04
3 ulnar	+0.14	+0.03	—	+0.21	+0.01	−0.30*	−0.12	+0.10	−0.29*	+0.07
4 ulnar	+0.13	−0.03	+0.08	—	+0.11	−0.15	−0.33*	−0.09	−0.23	−0.17
5 ulnar	+0.18	+0.05	+0.22	+0.20	—	−0.32*	−0.05	+0.19	+0.09	−0.05
1 radial	−0.26*	−0.19	−0.13	+0.05	−0.19	—	+0.15	+0.07	+0.06	+0.00
2 radial	−0.18	−0.45***	−0.16	+0.01	−0.10	+0.21	—	−0.12	+0.07	+0.09
3 radial	−0.21	+0.05	−0.13	−0.28*	+0.05	−0.06	+0.15	—	+0.22	−0.06
4 radial	−0.25	−0.08	−0.03	−0.13	−0.23	+0.01	+0.20	+0.05	—	+0.01
5 radial	−0.12	−0.02	+0.10	+0.05	+0.08	−0.03	−0.17	+0.04	−0.09	—

B. Fluctuating asymmetry

Finger pair	1 ulnar	2 ulnar	3 ulnar	4 ulnar	5 ulnar	1 radial	2 radial	3 radial	4 radial	5 radial
1 ulnar	—	+0.33*	+0.17	+0.21	−0.04	+0.22	−0.20	+0.09	−0.06	+0.06
2 ulnar	+0.15	—	+0.44***	+0.45***	+0.00	+0.10	+0.28*	+0.16	+0.11	−0.06
3 ulnar	+0.01	+0.18	—	+0.35**	+0.15	+0.12	+0.10	+0.27*	+0.07	+0.12
4 ulnar	+0.12	+0.06	−0.07	—	+0.14	+0.26	+0.31*	+0.21	+0.11	−0.03
5 ulnar	+0.15	+0.05	+0.18	+0.10	—	−0.01	+0.05	+0.23	−0.28	−0.15
1 radial	+0.16	+0.18	+0.02	+0.02	+0.15	—	−0.00	+0.04	+0.01	+0.07
2 radial	+0.26*	+0.44***	+0.09	−0.04	+0.01	+0.29*	—	+0.17	+0.15	−0.00
3 radial	−0.01	+0.18	+0.01	+0.17	+0.01	+0.06	+0.10	—	+0.09	−0.17
4 radial	+0.06	−0.11	−0.09	−0.00	−0.04	−0.07	+0.23	+0.17	—	+0.24
5 radial	+0.02	+0.10	+0.18	+0.23	+0.19	+0.16	+0.15	+0.30*	+0.11	—

Significance levels: $*P \leq 0.05$, $**P \leq 0.01$, $***P \leq 0.001$.

on's matched-pairs signed-ranks test). Out of the ten variables of fluctuating asymmetry, six show higher values in females but sex differences are not statistically significant for any of the variables at the 5% level (Mann-Whitney's *U* test).

Table 3 presents Spearman coefficients of correlation between the ten variables of fluctuating asymmetry. The coefficients range from −0.28 to +0.45 in males and from −0.11 to 7.44 in females. Of the 45 coefficients, the large majority is positive, and none of the negative coefficients reaches statistical significance at the 5% level. Only seven coefficients in males and four in females differ significantly from zero. The highest correlations ($P < 0.001$) are to be found in males between ulnar counts of

TABLE 4. Asymmetry ($\sqrt{A^2}$), intraindividual diversity ($S/\sqrt{5}$), total ridge-count (TRC), summed ulnar ridge-count (URC), and summed radial ridge-count (RRC) in Chilean Aymara Indians

	Males		Females		Significance of the sex difference[1]
	Mean ± SE	SD	Mean ± SE	SD	
$\sqrt{A^2}$	7.74 ± 0.45	3.36	8.55 ± 0.56	4.37	n.s.
$S/\sqrt{5}$	7.14 ± 0.37	2.72	7.53 ± 0.35	2.72	n.s.
TRC	150.89 ± 6.78	50.30	129.22 ± 6.35	49.20	*
URC	70.80 ± 7.43	55.10	58.08 ± 5.56	43.10	n.s.
RRC	137.07 ± 6.52	48.38	115.62 ± 6.29	48.72	*

[1] Mann-Whitney's *U* test (two-tailed) was used.

digits 2 and 3, and digits 2 and 4; in females between ulnar and radial counts of digit 2.

Indices of asymmetry ($\sqrt{A^2}$) and intraindividual ridge-count diversity ($s/\sqrt{5}$)

Means, standard errors of means, and standard deviations for the index of asymmetry ($\sqrt{A^2}$), the index of intraindividual diversity ($s/\sqrt{5}$), the total ridge-count (TRC), the summed ulnar ridge-count (URC), and the summed radial ridge-count (RRC) are presented in Table 4 for Aymara males and females.

As can be seen, mean asymmetry and diversity values are higher in females than in males, indicating more asymmetry and greater heterogeneity among fingers in females, but none of the differences reaches statistical significance at the 5% level. The mean ridge-counts for TRC, URC, and RRC are higher in males than in females, in agreement with the results of other authors (Karev, 1990) published so far. The male excess in TRC and RRC is statistically significant ($P < 0.05$, *U* test), but not in URC.

Males with the highest ridge-count means display lowest asymmetry and the greatest level of homogeneity among non-homologous fingers. In order to examine the relationship between TRC, $s/\sqrt{5}$, and $\sqrt{A^2}$, Spearman coefficients of correlation were calculated between these variables (Table 5). In both sexes, correlations between $s/\sqrt{5}$ and $\sqrt{A^2}$ are positive, while correlations of TRC with $s/\sqrt{5}$ and with $\sqrt{A^2}$ are negative. The correlation of TRC with diversity is higher than the correlation of TRC with asymmetry. Nevertheless, only the coefficient between TRC and $s/\sqrt{5}$ in males attains statistical significance ($P < 0.001$).

TABLE 5. Spearman coefficients of correlation between TRC, diversity ($s/\sqrt{5}$), and asymmetry ($\sqrt{A^2}$) values for male and female Aymara

Variables	Males	Females
TRC − $s/\sqrt{5}$	−0.48***	−0.20
TRC − $\sqrt{A^2}$	−0.10	−0.09
$s/\sqrt{5}$ − $\sqrt{A^2}$	+0.16	+0.22

Significance level: ***$P \leq 0.001$.

Population comparisons

Differences in asymmetry and diversity among populations of different ethnic backgrounds are of special interest. Important comparative studies were performed by Jantz (1974, 1975), who showed clear population differences between European and sub-Saharan African samples. Table 6 summarizes means of finger ridge-count diversities ($s/\sqrt{5}$) and asymmetries ($\sqrt{A^2}$) of the Aymara and 28 comparative samples from different regions of the world and from different ethnic backgrounds, including the samples studied by Jantz. All comparative data were taken from literature reports. The asymmetry data on Brazilian whites and blacks of Salzano and Benevides (1974) and Penhalber et al. (1994) could not be included because they are based on a different measure of asymmetry. Inspection of Table 6 shows that most data are available from European, Indian, African, and North American samples. The samples are arranged in different groups according to their ethnic ancestry. Indian samples are arranged in a separate group because they represent the

TABLE 6. Mean diversity ($s/\sqrt{5}$) and asymmetry values ($\sqrt{A^2}$) for 29 groups of different ethnic backgrounds

		Sample sizes		$s/\sqrt{5}$		$\sqrt{A^2}$		
No.	Group and ethnic ancestry	Males	Females	Males	Females	Males	Females	Reference
	Whites (Europeans, North Africans, Americans)							
1	Ohio, USA	169	196	7.2	7.6	9.3	9.3	Roche et al. (1979)
2	Tennessee, USA	133	132	7.35	6.94	8.98	8.80	Jantz (1975)
3	Englanders	151	151	7.88	7.18	9.20	9.10	Jantz (1975)
4	Bulgarians	1,065	1,065	7.40*	6.91*	8.86	8.72	Karev (1990)
5	Belgians	202	158	7.54	7.20	9.30	8.74	Leguebe and Vrydagh-Laoureux (1978)
6	Italians, southern Sardinia	233	231	7.47*	6.73*	8.05	8.16	Vona and Porcell (1983)
7	Italians, central Sardinia	264	249	7.02*	6.50*	7.32	7.85	Vona and Porcell (1983)
8	Italians, central Italy	217	181	6.56	6.47	8.23	8.44	Vona and Porcell (1983)
9	East European Jews,[1] Israel	206	133	6.77*	6.02*	7.98	8.67	Kobyliansky and Micle (1989)
10	Middle Eastern Jews,[2] Israel	147	106	6.45	6.37	8.09	8.10	Kobyliansky and Micle (1987)
11	Yemenite Jews, Israel	116	124	6.61	6.23	8.65	8.56	Micle and Kobyliansky (1987)
12	Mainly Moroccan Jews, Israel	197	127	6.30	6.31	7.74	7.81	Kobyliansky and Micle (1988)
13	Muzeina Bedouin tribe, Sinai	216	99	7.95	6.44	8.39	7.45	Kobyliansky et al. (1986)
14	Gebeliya Bedouin tribe, Sinai	116	—	8.22	—	9.74	—	Kobyliansky et al. (1986)
	Pooled Whites	3,432	2,952	7.23	6.78	8.56	8.53	
	Blacks (South Africans, Americans)							
15	Tennessee, USA	102	122	5.96	6.27	7.14	7.97	Jantz (1975)
16	Dogon, Mali	169	100	6.51	6.82	8.06	8.18	Jantz (1975)
17	Bedik-Bassari, Senegal	103	55	5.72	6.22	7.02	7.42	Jantz (1975)
18	Efe Pygmy, Zaire	152	53	5.55	5.49	7.41	7.69	Jantz (1975)
	Pooled Blacks	526	330	5.97	6.30	7.49	7.90	
	Polynesians							
19	Easter Islanders	146	141	6.83	6.54	8.17	7.93	Jantz (1975)
	Indians[3]							
20	Chitpavan	65	—	6.88	—	8.80	—	Chakraborty et al. (1982)
21	Chandra Seniya Kayastha Prabhu	54	—	6.33	—	8.08	—	Chakraborty et al. (1982)
22	Deshastha Rgvedi Brahmin	59	—	5.94	—	8.35	—	Chakraborty et al. (1982)
23	Maratha	78	—	5.92	—	7.00	—	Chakraborty et al. (1982)
24	Nava Budha	85	—	7.07	—	9.56	—	Chakraborty et al. (1982)
25	Bhil	94	—	6.81	—	9.77	—	Chakraborty et al. (1982)
26	Katkari	66	—	5.02	—	8.44	—	Chakraborty et al. (1982)
27	Pawra	64	—	5.41	—	8.84	—	Chakraborty et al. (1982)
28	Parsees	81	—	7.15	—	8.75	—	Chakraborty et al. (1982)
	Pooled Indians	646	—	6.34	—	8.68		
	Amerindians							
29	Aymara, Putre, Chile	55	60	7.14	7.53	7.74	8.55	Present study

*Sex differences in diversity are reported to be significant at least at the 5% level. No data on significance of sex differences were available for samples no. 1 (Ohio) and no. 13 (Muzeina).
[1] Originating from Poland, European USSR, and Romania.
[2] Originating from Iraq, Syria, and Iran.
[3] All samples were drawn from the Indian state of Maharashtra.

only Asiatic populations. For each larger group, pooled means (weighted) were calculated.

Diversity means range in whites from 6.30–8.22 in males and 6.02–7.60 in females; in blacks from 5.55–6.51 in males and 5.49–6.82 in females; in Indian males from 5.02–7.15 (female data were not available). Asymmetry values range in whites from 7.32–9.74 in males and from 7.45–9.30 in females; in blacks from 7.02–8.06 in males and 7.42–8.18 in females; in Indians from 7.00–9.77 in males. The different ethnic groups can be ranked with regard to increasing diversity as follows (for blacks, whites, and Indians, pooled means are considered):

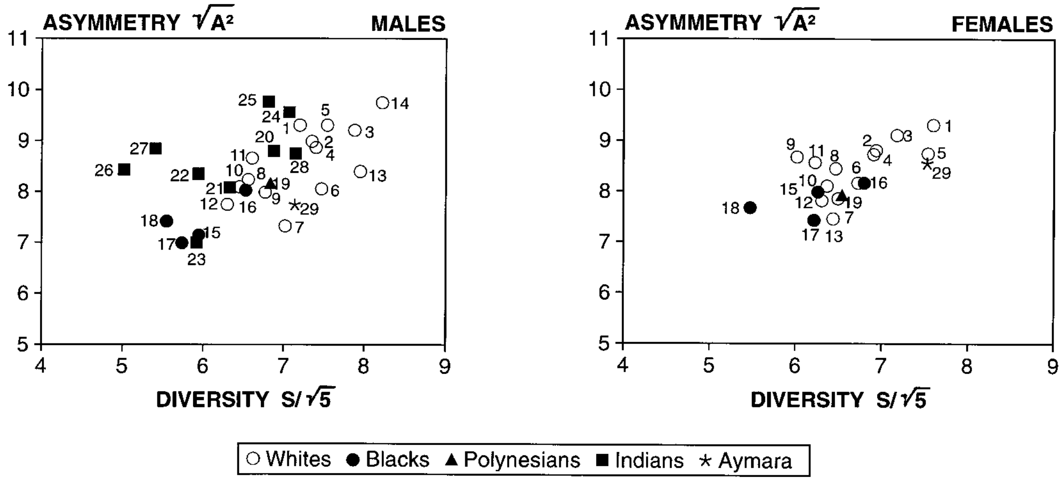

Fig. 2. Bivariate plot showing the relationship between mean values of diversity ($s/\sqrt{5}$) and asymmetry ($\sqrt{A^2}$) for the Aymara Indians and 28 comparative samples of different ethnic backgrounds. Numbers of male (left) and female samples (right) indicate their source (see Table 6 for key).

blacks < Indians < Aymara < whites. For asymmetry, the ranking is: blacks < Aymara < whites < Indians. The sequences are the same in both sexes, except that in females the positions of the Aymara and whites are exchanged.

With regard to sex differences, it is noticeable that in most white groups males exceed females in their diversity values, while the reverse is true among most black groups and in the Aymara. Nevertheless, significant sex differences are only reported for some white groups, all of them showing males to have larger diversity values than females. Concerning asymmetry, values are greater in males in half of the white samples, while all black samples and the Aymara show larger values in females. However, all sex differences in asymmetry are reported to be nonsignificant.

Next, for each of the 29 samples the asymmetry mean was plotted against the diversity mean (Fig. 2). As can be seen, clear ethnic differences emerge. In both sexes, white samples generally have larger asymmetry and diversity values than black samples. The greater diversity values in white groups indicate that their ridge-counts are more heterogeneous than those of black groups. The Aymara males are characterized by higher asymmetry than most blacks, and lower asymmetry than most whites. Diversity values in Aymara males are higher when compared to blacks, lying within the lower variability range of whites. Like males, Aymara females show higher asymmetry and diversity values in comparison with blacks. In contrast to the values of Aymara males, female asymmetry and diversity values lie in the upper range of means acquired through white samples.

A discriminant analysis was performed in order to show clustering of the populations of the same ethnic background. The analysis was restricted to male samples, as the discriminant function yielded no significant intergroup variation for female samples. The analysis was based on the variables $s/\sqrt{5}$ and $\sqrt{A^2}$ taken from the 29 male samples listed in Table 6. Three groups were defined (whites, blacks, and Indians), whereas the Aymara and Polynesians were not assigned a priori to any group.

The canonical discriminant functions are given in Table 7. Wilks's lambda indicates high intergroup heterogeneity ($P < 0.0003$, $P < 0.0072$) and permits a significant separation of the three groups (whites, blacks, Indians). The first two canonical variates explain 69% and 31% of the total dispersion. The variable $s/\sqrt{5}$ shows highest loading in

TABLE 7. Results of the discriminant analysis by means of the traits diversity and asymmetry (29 male samples, listed in Table 6)

Function	Eigenvalue	Percentage of variance	Function removed	Wilks' lambda	Chi-square	d.f.	*P*
			0	0.408	21.07	4	0.0003
1	0.8030	69.08	1	0.736	7.22	1	0.0072
2	0.3595	30.92					

TABLE 8. Classification results of the discriminant analysis for 29 male samples (listed in Table 6)

Real group	No. of samples	Predicted groups		
		Whites	Blacks	Indians
Whites	14	11 (78.6%)	2 (14.3%)	1 (7.1%)
Blacks	4	0 (0%)	4 (100%)	0 (0%)
Indians	9	2 (22.2%)	2 (22.2%)	5 (55.6%)
Ungrouped*	2	2 (100%)	0 (0%)	0 (0%)

Percent of "grouped" samples correctly classified: 74.07%

*Aymara and Polynesians.

the first discriminant function, whereas the variable $\sqrt{A^2}$ has maximum influence on the second function. The population covariance matrices are homogeneous across the groups (Box's $M = 4.90$, $P = 0.6785$). The overall percentage of samples correctly assigned to one of the three original groups is 74.07% (Table 8). The result is relatively good when taking into account that only 33.3% of the samples would be expected to be identified correctly by chance. Nevertheless, there is a tendency to underestimate the misclassification, as most samples used for the calculation of the discriminant statistics are also used for selection purposes. A splitting of the samples was not possible because the available dataset was not large enough.

As can be seen, the highest proportion of samples that are identified correctly is to be found among the black samples and the lowest among the Indian samples. Two Indian samples are misclassified as whites (Chitpavan, Parsees) and two as blacks (Chandra Seniya Kayastha Prabhu, Maratha). White samples that are predicted incorrectly are the Yemenite Jews (classified as Indians), and the Middle Eastern and Moroccan Jews (classified as blacks). Of special interest is the classification result of the ungrouped samples, the Aymara and the Polynesians. They were both assigned with the highest probability to the white group and with the second highest probability to the black group.

DISCUSSION

Most studies published on dermatoglyphic asymmetry and diversity are restricted to populations of Indo-European and African ancestry, while there is no information on how much local variation there may be in Amerindians. One objective of the present study was to fill this gap, presenting data on finger ridge-count asymmetry and diversity in an Amerindian group. The limited data available from the Chilean Aymara suggest that asymmetry exists for finger ridge-counts, and that the amount of directional asymmetry in females exceeds that of males. However, differences between the sexes in directional and fluctuating asymmetries are less pronounced than differences between non-homologous fingers. Females also tend to have higher asymmetry and diversity indices than males, but the findings did not reach statistical significance. Positive correlations between asymmetry and diversity found in the Aymara are in agreement with results presented by other authors (Leguebe and Vrydagh-Laoureux, 1978; Vona and Porcell, 1983). In the Aymara, negative correlations exist between diversity and TRC, and between asymmetry and TRC. The same findings have been reported for Belgians (Leguebe and Vrydagh-Laoureux, 1978), Is-

raeli Jews (Micle and Kobyliansky, 1988), Italians (Vona and Porcell, 1983), most of the samples investigated by Jantz (1975), and by Chakraborty et al. (1982). Unfortunately, there are no comparative data on other Amerindian groups available. Therefore, further data on various Native American populations are needed in order to obtain a general overview of the extent of variation in asymmetry and diversity among them.

Fluctuating asymmetry

The results on fluctuating asymmetry are of special interest in terms of the hypothesis that females are generally better canalized than males and that they exhibit less asymmetry in finger ridge-counts. The present study showed a tendency towards a somewhat higher, but statistically nonsignificant, fluctuating asymmetry of radial and ulnar finger ridge-counts in Aymara females than in males. The observations are in accordance with those of Micle and Kobyliansky (1991), who found significantly greater fluctuating asymmetry in females among Israeli Jews. In contrast, Karev (1988) reported no considerable sex differences for a Bulgarian sample. Nevertheless, the findings at hand contradict the hypothesis that females are generally better canalized than males and that they show less asymmetry in finger ridge-counts.

There are different attempts to explain this discrepancy. Micle and Kobyliansky (1991) state the possibility that male embryos with high levels of fluctuating asymmetry are eliminated by selection because they are subject to higher rates of spontaneous abortions and have unusual dermatoglyphics (Babler, 1978; Stinson, 1985). Karev (1988) concluded from his findings in Bulgarians that large inter-finger differences observed in fluctuating asymmetry, along with very low and mainly nonsignificant finger-to-finger correlation coefficients "indicate that any general buffering capacity is apparently absent" (p. 251). He goes on to say that the nature of asymmetry in each sex may play a more important role than the question of which sex shows a larger asymmetry. Sorenson-Jamison (1988) discussed the effect of prenatal testosterone on intrauterine dermal ridge formation and as a possible causative factor in dermatoglyphic variation. Jantz (1987) pointed out that only as ridge-counts approach the means, biological factors will control asymmetry. Otherwise, structural limitations will be important so that asymmetry will be damped. For example, individuals with low ridge-counts or with arches on both sides will show less asymmetry. With regard to the sexes, most studies have shown that, generally, females have lower ridge-count means on the fingertips, along with more arches and fewer whorls than males (Cummins and Midlo, 1961). Thus, sex differences in asymmetry could partly be the result of structural limitations.

Finger ridge-counts will not be altered by postnatal environmental influences, while prenatal uterine factors can affect their development. Therefore, variations in fluctuating asymmetry could result from differences in the local developmental environments. The formation of dermal ridges occurs before the nineteenth gestational week following conception (Cummins and Midlo, 1961; Mulvihill and Smith, 1969; Penrose and Ohara, 1973; de Wilde, 1979), implying that ridge-count development can only be affected by environmental factors operating prior to the nineteenth week. Studies have shown that dermatoglyphic characters are very sensitive indicators of disturbances in the intrauterine development (Adams and Niswander, 1967). Borecki et al. (1985) reported significant intrauterine environmental effects for the total palmar pattern ridge-count and the distal palmar pattern ridge-count. The exposure to various environmental stress factors such as cold, heat, noise, malnutrition, certain chemicals, etc., as well as low socioeconomic level may influence dermatoglyphic asymmetry. However, Parsons (1992) demonstrated that under field conditions relatively severe stress is needed to increase fluctuating asymmetry. He concluded that increased fluctuating asymmetry tends to be found in stressed marginal regions.

The present Aymara sample comes from such a marginal habitat. They live at high altitude, being exposed to hypobaric hypoxia as the main stressor. This study showed that Aymara males are characterized by intermediate and females by high asymmetry values when compared to other populations. There-

fore, the question is whether high-altitude hypoxia may affect prenatal ridge formation. It has been shown that a fetus experiences a greater degree of hypoxia in utero at high altitude than at low altitude (Ballew and Haas, 1986). A comparative study by Parham (1985) on dermatoglyphic data of highland and lowland Quechua Indians demonstrated that highlanders exhibit higher palmar a-b ridge-counts and lower c-d counts than lowlanders. Parham explained the intraethnic differences by developmental modifications in highlanders as a result of the hypoxic stress at high altitude. The question may now be asked in what way hypoxia can exert an influence on the formation of dermal ridges and their asymmetry. One can speculate that hypoxia may affect the formation of blood vessels and, thus, indirectly, of dermal ridges. According to Siervogel et al. (1978, p. 554) "environmental factors could involve similarities or dissimilarities among digits in. . .blood supply." Hirsch and Schweichel (1973) stated that the conditions of blood vessels and oxygen supply may have an effect on dermatoglyphic development. Bonnevie (cited by Cummins and Midlo, 1961) assumed that the blood sinus in the finger ball may influence the differentiation of ridges, while Steffens (1938) does not consider the blood sinus as a likely regulatory factor. At the moment, no definitive conclusions can be drawn on this topic. Further data are needed from highland populations in order to assess the effects of high-altitude hypoxic stress on the intrauterine dermal ridge formation during prenatal development. It would be of particular interest to compare the amount of fluctuating asymmetry in a stressed highland sample to that in a nonstressed lowland sample of the same ethnic origin. In addition, the role of genetic factors could be evaluated by studying differences in asymmetry among genetically different samples living in the same or a similar high-altitude environment, e.g., Amerindians vs. Europeans.

Population comparisons

Jantz (1975) assumed that the genetic mechanisms underlying dermal ridge differentiation might also influence the amount of developmental stability, which in turn would lead to varying expressions of ridge-count asymmetry and diversity. Singh had already stated in 1968 that the asymmetry measure $\sqrt{A^2}$ can be used to detect ethnic differences. The present comparison between population samples from different ethnic backgrounds demonstrated the existence of ethnic differences with respect to finger ridge-count asymmetry and diversity. The results indicate that asymmetry and diversity values tend to be low in black populations, high in white populations, and intermediate in the Aymara, while Indian groups are characterized by high asymmetry and low diversity values.

The findings are in agreement with the results of various other studies that also demonstrated higher values in white populations when compared to black populations. For example, by performing comparative studies on groups of European and African ancestry, Jantz (1974, 1975) demonstrated ethnic variation in ridge-count asymmetry and diversity with higher values in Europeans. Salzano and Benevides (1974), in a study based on Brazilian samples, also found a higher finger ridge-count asymmetry in whites than in blacks. Likewise, higher amounts of fluctuating asymmetry have been reported for the palmar a-b ridge-count in Europeans as opposed to Africans (Jantz and Webb, 1982). Moreover, Malhotra (1987) demonstrated, based on the comparison of 69 populations worldwide, that Europeans show the largest and Africans the smallest variance in fluctuating asymmetry of the total finger ridge-count, while other populations occupy intermediate positions.

Regarding the Indian groups, the present study showed a considerable variation in diversity and asymmetry, when taking into consideration that all groups originate from the same state in western India. The high asymmetry values in some tribes may be influenced by their endogamy. This is supported by the findings of Markow and Martin (1993), who demonstrated a significantly higher amount of dermatoglyphic asymmetry in inbred groups in comparison to noninbred groups. Inbreeding is accompanied by reduced heterozygosity and increased homozygosity. For homozygous individuals, an increased amount of dermatoglyphic

asymmetry has been shown (Kobyliansky and Livshits, 1986). The high asymmetry and diversity means in males of the two Bedouin tribes of the Sinai desert (samples nos. 13 and 14, Table 6) can be interpreted in the same context. Their high asymmetry can be explained by their biological isolation and consanguinity, because marriages between first cousins amount to 15% of the total marriages (Kobyliansky et al., 1986). As Livshits and Kobyliansky (1987) have shown that heterozygous individuals tend to have lower values of ridge-count diversity, the high diversity values of the Bedouin tribes might also be attributed to their higher degree of homozygosity.

The present interpopulation comparisons not only reveal ethnic differences in asymmetry and diversity, but also indicate geographical variation. There appears to be a cline through Europe, the Middle East, and Africa such that asymmetry and diversity values tend to decrease from the northern to the southern hemisphere. Accordingly, the highest values are to be found in populations of northern Europe (England, Belgium, Bulgaria), intermediate values in southern Europe (Italy) and northern Africa (Israel), and lowest values in sub-Saharan Africa (Mali, Senegal, Zaire). Here, populations of the northern hemisphere are characterized by greater ridge-count variability and heterogeneity among fingers than populations of the southern hemisphere. Nevertheless, the data are insufficient to say whether this trend also applies to populations of East Asia and America. Particularly, the Aymara of South America look more like northern hemisphere populations than southern ones in their asymmetry and diversity values. This is confirmed by the results of the discriminant analysis.

The question is to what extent the geographical variation observed can be attributed to genetic and environmental influences on prenatal dermal ridge-count formation. Generally, it can be assumed that the relative contribution of genetic and environmental factors may differ in populations of different ethnic backgrounds. The gradient observed is not in accordance with ecological factors. Thus, it can be assumed that it indicates varying degrees of miscegenation and heterozygosity pointing out to genetic factors. This agrees with the results of Jantz and Webb (1982) who studied interpopulational differences in fluctuating asymmetry of the palmar a-b ridge-count. The authors could not establish any environmental relationship and found that African groups have higher correlations, i.e., lower asymmetry, than European, Asian, and Amerindian groups. They suppose that there is a genetic component in the magnitude of asymmetry and concluded from their results that "a sizable fraction of variation in fluctuating asymmetry is related to geographical" groups (p. 253).

With regard to genetic factors, further results have been given. Jantz and Hawkinson (1980) performed a principal components analysis on ulnar and radial finger ridge-counts of black and white populations and found that a "difference in the nature or strength of a growth gradient during morphogenesis of the ridged skin system" exists between these groups (p. 143). The authors further cited an unpublished work of Babler (1977) who demonstrated differences in ridge maturation between black and white populations. Jantz (1987) reported for ridge-counts an overall heritability estimate of 0.738, based on 20 finger ridge-counts. Different authors studied the variation of the indices of asymmetry and diversity in population groups of the same ethnic origin that have been living in different geographical regions for longer periods of time. For instance, Kobyliansky et al. (1979) studied Jewish Israelis from eastern Europe, central Europe, the Middle East, and northern Africa; Jantz (1975) examined black groups from Africa and America. In both studies, small intraethnic differences in diversity and asymmetry were found, indicating that genetic factors may possibly have more influence on these variables than environmental factors.

In conclusion, the present results show interpopulational and geographic differences in finger ridge-count asymmetry and diversity. The findings suggest, in agreement with other studies, that the measures of $s/\sqrt{5}$ and $\sqrt{A^2}$ are suitable for comparative population studies in dermatoglyphics. In order to learn about variation among Native

Americans, more population data on Amerindian samples from different ecosystems are required.

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